COMPUTER BASED INSTRUMENTATION SYSTEM FOR PRESSURE MEASUREMENT IN MATLAB APPLICATION

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ABSTRACT

This project presents a mechanism of collecting data from a process control plant. Generally, this project based on process control that used the instrument to measure pressure in kPa and converted the output to the current in mA. This project used the equipments from the experiment and built the system using MATLAB, graphical user interface (GUI) to manipulate the data. From the data, students can do investigations and analysis such as plot the graph of the output and error, and uncertainty of the measurement for the calibration of the pressure transmitter. This mechanism will help students during their laboratory session. In order to support the system, data acquisition card, PCI 1710HG will be used to transfer data from pressure transmitter to the computer. The result will be displayed in the GUI including the data that have been transfer from the instrument to the computer. The graph of five-point calibration and error also shown. In addition, the results of the calculation for average and error of the data, standard deviation, combined standard uncertainty and the effective degree of freedom to get the uncertainty are included in the study analysis. Students can use this proposed mechanism to do the data analysis which is very convenience for the lab session. This system will benefit not only the students but also for the instructor.

ABSTRAK

Projek ini menerangkan mekanisma pengumpulan data daripada pelan kawalan. Secara umumnya, projek ini berdasarkan pengawalan proses yang menggunakan alat-alat untuk mengukur tekanan dalam unit kPa dan menukar hasilnya kepada unit arus dalam mA. Projek ini juga menggunakan alat-alat tersebut untuk menjalankan eksperimen dan membina sebuah sistem menggunakan MATLAB GUI untuk memanipulasi data. Pelajar-pelajar boleh menganalisa data-data yang diperolehi daripada eksperimen tersebut dengan memplot graf hasil and kesalahan, ketidakpastian ukuran bagi pengujian pemancar tekanan. Sistem ini boleh membantu pelajar-pelajar semasa menjalankan eksperimen di makmal. Selain itu, ‘data acquisition card’, PCI 1710HG akan digunakan untuk memindahkan data daripada pemancar tekanan kepada system di dalam computer. Keputusan analisis akan ditunjukkan di GUI termasuk data yang telah dipindahkan. Graf 5-titik pengujian dan kesalahan juga ditunjukkan. Selain itu, jawapan kepada pengiraan purata dan kesalahan data, selisihan ukuran, gabungan ketidakpastian dan efektif darjah kebebasan untuk mendapatkan ketidakpastian adalah termasuk di dalam analisis. Para pelajar boleh menggunakan sistem cadangan ini untuk membuat analisis yang akan memudahkan eksperimen di makmal. Sistem ini juga akan memberi faedah bukan sahaja kepada para pelajar malah kepada tenaga pengajar.

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CHAPTER 1

INTRODUCTION

1.1 Background

Process Control is the automated control of a process. Process control is used extensively in oil refining, chemical processing, electrical generation and the food and beverage industries where the creation of a product is based on a continuous series of processes being applied to raw materials [1]. The Faculty of Electric & Electronics Engineering has a laboratory complete with instruments which is used in control system. This project is using those equipments to do the experiment and build a system to manipulate the data that obtained from the experiment so that students can do the study analysis such as plot the graph of the output and error, uncertainty of the measurement for the calibration of the pressure transmitter.

In current laboratory Industrial Instrumentation subject session, students do the five-point calibration of pressure transmitter to get the current reading. They also plot the graph for five-point calibration and graph for error of the pressure transmitter. The uncertainty evaluation also calculated manually. The idea to develop this system using MATLAB is to help students to do study analysis during laboratory session. Beside that, data acquisition card, PCI 1710HG will be used to transfer data online from pressure transmitter to the system in computer.

1.2 Objective

This project has three major objectives which are understand the basic measurement principles of pressure transmitter, recognize the hardware that can be used to transfer data from instrument which is pressure transmitter to the computer, and develop software that can be implemented in laboratory session for Industrial Instrumentation course, BEE4523, that helps students in study analysis.

This project is based on instrumentation for pressure measurement that needs to know how to use pressure transmitter and other devices used in the experiment. Understand the basic principles will lead to the successful of the experiment. To connect between instrument and computer, hardware will be needed to transfer the data. It must be suitable so that the transferring process do not facing any problem.

The main objective of this project is to develop system that can be implemented in laboratory session for Industrial Instrumentation course. This system can be used to do study analysis so that it will be easier to the students to conduct their laboratory session.

1.3 Project Goal

The hardware used, PCI 1710HG will transfer the data measured from the pressure transmitter to the system in the computer in real-time application and the system does the study analysis. In addition, this project will benefit the students while conducting a laboratory experiment in Industrial Instrumentation subject, BEE4523. Students can use the proposed system for measuring pressure, calculating the output error, getting the graph for five-point calibration, graph error and evaluate the uncertainty.

1.4 Project Scope

To achieve the objective of this project, several work scopes are determined. The scope that has been proposed to the project includes study the basic measurement principles of pressure transmitter, search about data acquisition that will be needed to use as hardware to transfer the data and explore how to use MATLAB and studying the other programs using MATLAB to develop a system.

To understand the basic measurement, studying is the most important in order to use the instrument correctly without parallax error while taking the data. To determine the DAQ card that is suitable to transfer data from pressure transmitter to the computer, some research about data acquisition is needed to confirm the type of the DAQ card.

The system that will be designed is using MATLAB GUI that never been used before. Mastering this software is important in order to develop the system. Studying the function of coding and practicing in build the program using MATLAB will help the most to develop the system.

1.5 Thesis Overview

This thesis consists of 6 chapters that clarify about the system entitled computer based instrumentation system for pressure measurement in MATLAB application. Each chapter described about important part of the project such as the hardware and software development.

The first chapter divided into 5 parts which are the background of the project, objectives, project goal, project scope and the overview of the thesis.

Literature review is included in chapter II. A literature review is a body of text that aims to review the critical points of current knowledge on a particular topic and most often associated with science-oriented literature. [2] Literature review is also known as the current practice that has been used now.

The hardware includes the instruments used in the experiment, theory of pressure measurement and explanation of data acquisition card is explained in chapter III which is hardware part. The methodology is also included in this chapter. Beside that, the interfaces between the hardware and the system and the real-time application also explained.

In chapter IV, the contents are about the software that has been developed. The functions of the GUI that have designed are described in this chapter.

Chapter V explained the results of this project and includes the discussion while chapter VI is the conclusion and the future development and recommendations.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter discussed about literature review that is mostly taken from journals and books. Internet sources also use to add more information about this project. The journals taken after considered the content which are either related or not to this project. The purpose of doing literature review is to find, read, and analyze the body of literature published on this project. This information can be used to improve this project as well.

2.2 Instrumentation

Many techniques have been developed for the measurement of pressure such as manometer that is limited to measuring pressures near to atmospheric, bourdon tube gauge that uses a coiled tube which as it expands due to pressure increase [3]. This article is about techniques to measure the pressure and it gives some examples of instrument that can be used to measure the pressure. The selection of instrument is very important to adapt it to the current situation or to the project conducted.

A pressure transducer is fundamentally any device that converts an applied pressure into an electrical signal. There have been many different types of pressure transducer developed over the years such as bonded foil, thick film, thin film & semiconductor strain gauge. All of these sensing technologies are pressure transducers and they provide an electrical signal typically a millivolt output signal which varies with changes in pressure when connected to an appropriate power supply. A pressure transmitter is simply a pressure transducer with some extra electronics to transmit a 4 to 20 mA output signal. At first pressure transmitters would only be found in large process plants and the sensors were bulky and relatively expensive. In recent years other industries have adopted the 4 - 20mA output signal pressure transmitter. An amplified voltage output is much more robust than a millivolt output signal and can be used over mediums distances without any noticeable signal losses. Typically only a few resistor components are required to condition the millivolt output from a strain gauge pressure sensor. Current output pressure transmitters for gauge, absolute & differential pressure sensing where a robust 2 wire 4 - 20mA current output loop is required which can work over long distances without signal degradation [4].

This article is about difference between pressure transducer and pressure transmitter. They produce an electrical signal such as in milivolt or in miliampere. There are many advantages on pressure transmitter over pressure transducer such as they are robust, unnoticeable signal loses and can work over long distances without signal degradation.

A transducer is a device which converts one form of energy into another form of energy. In the field of electrical instrumentation, “a transducer is defined as a device which converts a physical quantity, a physical condition, or mechanical output into an electrical signal”. Most of the methods of converting mechanical output into an electrical signal work equally well for the bellows, the diaphragm and the Bourdon tube. In this conversion, a mechanical motion is first converted into a change in electrical resistance and then the change in resistance is converted into a change in electrical current or voltage. Electrical pressure transducer consists of three elements:

1. Pressure sensing element such as bellow, a diaphragm or a Bourdon tube
2. Primary conversion element, e.g. resistance or a voltage.
3. Secondary conversion element

Pressure instrument calibration is the process of adjusting the instruments output signal to match a known range of pressures. All instruments tend to drift from their last setting. This is because spring stretch, electrics components undergo slight changes on the atomic level, and other working parts sag, bend, or lose their elasticity. Basic calibration procedure includes zero, span, and linearity adjustments. Proper calibration provides the desired beginning and ending pressures, and produces an output signal that is proportional to the process pressure. Calibration of the instrument is carried out by applying to it an air or liquid pressure whose value is accurately known. The method used depends upon the range of the instrument [5].

2.3 Current Signal and Voltage Signals

There are two types of signals that can be resulted from the experimentation of pressure which are voltage signal and current signal.

Voltage signals are normally standardized in the voltage ranges 0 to 5 V, 0 to 10 V, or 0 to 12 V, with 0 to 5 V being the most common. The requirements of the transmitter are a low output impedance to enable the amplifier to drive a wide variety of loads without a change in the output voltage, low temperature drift, low offset drift, and low noise. Its low output impedance enables the driver to charge up the line capacitance, achieving a quick settling time. Current signals are standardized into two ranges; these are 4 to 20 mA and 10 to 50 mA, where 0 mA is a fault condition. The latter range was the preferred standard but has now been dropped, and the 4 to 20 mA range is accepted standard. The requirements of the transmitter are high output impedance, so that the output current does not vary with load, low temperature, offset drift, and low noise. The main disadvantage of the current signal is its longer settling time due to the high –output impedance of the driver which limits the available current to charge up the line capacitance. After the line capacitor is charged, the signal current at the controller is the same as the signal current from the transmitter and not affected by the normal changes in lead resistance. The internal resistance of the controller is low for current signals i.e., a few hundred ohms. Again a differential signal connection eliminates noise and ground problems [6].

For the highest possible pressure sensor accuracy it will need an output signal which is not easily corrupted and has a very high resolution. Digital output signals do not suffer from signal losses or interference like analogue ones do, either the complete signal gets through as originally transmitted from the pressure sensor or none at all [4]. This article is about the advantages using digital output signal than using analog output signal. To get a high resolution on the output signal, an analogue to digital converter is needed. There is no need to convert a digital signal to analogue because it can be easily interfaced to a computer or data acquisition card via a digital connection. Another benefit is the microprocessor inside the DAQ is also digital so that can eliminate linearity errors.

2.4 Data Acquisition Systems and Real-Time Applications

Data acquisition systems (DAS) interface between the real world of physical parameters, which are analog, and the artificial world of digital computation and control. With current emphasis on digital systems, the interfacing function has become an important one; digital systems are used widely because complex circuits are low cost, accurate and relatively simple to implement. In addition, there is rapid growth in the use of microcomputers to perform difficult digital control and measurement functions. Computerized feedback control systems are used in many different industries today in order to achieve grater productivity in our modern industrial societies. The device that perform the interfacing function between analog and digital worlds are analog-to-digital (A/D) and digital-to-analog (D/A) converters, which together are known as data converters [7].

Some data-acquisition boards are designed to interface with several different sensors. The sensor support includes sensor excitation, linearization, cold reference compensation, and conversion of the output to engineering units. Multisensors plug-in boards typically contain four sections. The first section performs the signal conditioning for the sensors, multiplexes to the appropriate sensor and amplifies the signal with a programmable gain. The second section performs A/D conversion. The third section incorporates a microcomputer with on-board memory used in data processing to perform tasks such as linearization, reference junction compensation, and engineering unit conversion. The microprocessor also provides the logic to scan the sensors, adjust the amplifier gain, and transfer the data to the standard bus registers. The standard bus interface incorporates drivers and receivers to facilitate communication with a PC host computer. The input/output ports vary from card to card, but a typical configuration that utilizes serial communication has three ports. One port is used to transfer data and instructions to the card, and the other two ports are used to transfer data and indicate status to the host computer. The card is programmed from the PC host computer and the digitized data are transferred from the card to the memory of the PC using standard bus in the host computer. External bus structure is not required for data transmission, because the entire data-acquisition system is contained within the PC. All further processing and preparation of graphics are performed on the host computer using commercially available software [8].

Besides A/D and D/A converters, data acquisition and distribution systems may employ one or more of the following: transducers, amplifiers, filters, nonlinear analog functions, analog multiplexers, and sample-holds. The interconnection of these components makes a portion of a computerized feedback control system. The input of the system is a physical parameter such as temperature, pressure, flow, acceleration, and position, which are analog quantities. The parameters are first converted to electrical signal by means of transducer; once in electrical form, all further processing is done by electronic circuits.

Real-time operating system is needed to do this project. Operating system arbitrates and controls the resources of a computer system and resolves conflicts, optimizes the performance, helps the user to easily implement device-oriented application programs. The software in the computer used this application to collect the data from instruments. There are specific ways to set the configuration of the real-time operation depends on the software used. RTOS is used for the process control computer application. It is capable of managing real-time resource scheduling and control problems in computer based industrial process control systems. Any real-time computer system must be able to respond interrupts from external devices [5].

A project based on an array of metal oxide sensors (MOS) devices has been develop referring to the paper by Hsin-Ti Chueh and john V. Hatfiled. A dedicated real-time data acquisition system with programmable voltage generator, self-calibration techniques and custom visual software programs for a desktop PC and a hand-held computer have been designed and constructed for this application. This paper also describes an example of software calibration to correct source errors for this data acquisition system. Experimental results show that this data acquisition system can accurately measure a large range of resistive sensor responses and is suitable for measuring both conducting polymer and MOS sensors [9].

The data acquisition system designed is explained in details. Sensor arrays, where each sensor has low specificity, need appropriate data acquisition system and pattern recognition software to recognize simple and complex odors. The data acquisition systems interact continuously with the environment and embedded software synchronously reads the sensor data and controls the circuits [9].

2.5 MATLAB

"Using MATLAB with the Instrument Control Toolbox and the Data Acquisition Toolbox helped us to meet our project's deadline and make our project successful" Reed

Farrar, Newport Corporation [10]. This is actually user's story about Newport Corporation that develops a variety of products for the semiconductor research industry that requires quick and accurate analysis of test data. They have found out that using MATLAB is the fastest way to analyze results from the instruments. They used to spend days on just one test but with MATLAB they can run the same test and analyze the results in a few hours. Newport increases the efficiency and quality of test data by using MATLAB, the Instrument Control Box and the Data Acquisition Toolbox to acquire and analyze measurement results from within a single environment.

A MATLAB-based graphical user interface (GUI) program has been develop and implemented for tomographic viscometer data processing. The tomographic viscometer is based on a velocity profile measurement using magnetic resonance imaging (MRI) or ultrasonic Doppler velocimetry (UDV). This program enables users to process image data, to calculate rheological properties and to visualize results [11]. This paper presents a MATLAB-based software program for analysis of fluid rheological properties. The program structure is about allowing users to process tomographic data from either MRI or UDV and to calculate the rheological properties immediately after data acquisition.